Central and autonomic indices of response inhibition

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Published in:
Journal of Psychophysiology

Publication date:
1997

Journal of Psychophysiology 11 (1997) 90–99

Abstracts of the Summer Conference of the Dutch Society for Psychophysiological Research held in Amsterdam, June 18, 1996

LRPs during inhibition of a primed response: Are children more impulsive than adults?

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Children's ability to adjust responses was assessed with performance measures and lateralized readiness potentials (LRP). Subjects of age 7, 10 or 21 prepared a primed response during a 1500 ms interval before target onset. On a minority of trials (20%), the target instructed subjects to give a response with the hand opposite to the primed hand (change-trials). On all other trials, the target indicated that the primed response should be executed (go-trials).

A sharp decrease of the number of impulsivity errors (responses with the primed hand on change trials) occurred between 10-year-olds and adults. The delay of changed responses relative to go-trials decreased with age, suggesting more flexibility in response production for adults. In both conditions LRPs were positive just after target onset, even though fast preparation for the primed hand was expected to cause a negative potential on go-trials. On change-trials this positivity persisted longer and became larger than on go-trials. The typical explanation of an initial positivity as a reflection of preparation for the incorrect hand cannot account for these data. This pattern could mean that during the accumulation of evidence for the correct response, there was active suppression of its execution. Moreover, if it was realized that the prime was not valid, subjects inhibited the correct response even more strongly, in order to reduce the risk of issuing the primed response instead. The LRP data support the impression from the performance data that children of age seven and 10 were less flexible in overruling incorrect response preparation: Children's LRPs showed a substantially larger initial positivity than adults' LRPs.

Metrical stress in speech recognition: An explorative ERP study

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Metrical stress (the pattern of weak and strong syllables) is one of the qualities of speech. It lends speech its rhythm or prosody. There is some support for the notion that in languages like Dutch and English metrical stress is necessary for segmenting speech and the detection of word boundaries. This possibility arises because bisyllabic words with a strong-weak stress pattern (like BORstel) are far more common than those with a weak-strong pattern (like beTON). According to the alternative explanation speech segmentation is the result of word recognition and is achieved by postlexical instead of prelexical processing. We describe an ERP component which proved to be sensitive to metrical stress and, after validation, can be used in psychochronometrical studies into the role of metrical stress in speech perception. This ERP component, which we named Prosodic Negative Shift (PNS), is the extra negativity which follows the presentation of weak-strong words. It has a left frontocentral maximum and a peak latency of 350 ms, between P2 and N400. It is at the interface between the exogenous stress effects on the N1 and P2 and the endogenous N400 and P600, which are modulated by task variables but not by metrical stress. The subgroup of subjects who were good discriminators of the stress pattern (n = 9, < 1% errors on average) showed PNS amplitudes related to the response categories and large N400-P600 amplitudes, whereas bad discriminators (n = 9, 5–10% errors on average) did not show differential PNS amplitudes.

Tonic facial EMG activity as an index of mental effort: effects of work rate, time-on-task, and achievement motivation

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In previous studies, we have observed gradually increasing EMG activity in certain facial muscles (corrugator supercilii and frontalis) during the performance of different types of information processing tasks. These so-called EMG gradients were interpreted as indicating increasing mobilization of aspecific energetic resources ("compensatory mental effort"). We hypothesized that EMG gradients reliably reflect effects of achievement motivation and variables affecting the subject's energetic state, such as work rate and time-on-task. The effects of these variables were more closely investigated in the current study in which 40 subjects performed a warned visual choice reaction time task. Repetition rate of reaction time trials was varied between trial blocks. Three different rates were presented in a counterbalanced order. Following a short rest period, the three trial blocks were presented a second time. It was expected that faster presentation rates as well as time-on-task would induce higher compensatory mental effort. Achievement motivation was also manipulated. Half of the subjects received feedback following each trial in combination with monetary incentives, whereas the other half did not receive feedback or incentives. EMG gradients in corrugator and frontalis were larger in the reward than in the non-reward group. In the former group, they were at a constant high level in the three work rate conditions, whereas in the non-reward group they increased with work rate. When the three trial blocks were repeated, EMG gradients increased in both groups. These results support the hypothesis that EMG gradients in corrugator and frontalis reflect the mobilization of mental effort due to task demands, time-on-task, and achievement motivation.

Localization of early visual processing and effects of spatial attention

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Subjects were shown a square in 1 of 4 quadrants (eccentricity 6.1 degrees). This probe was preceded (SOA 142 ms) by a target dot at either the same or a different location. The attention-attracting effects of the target on the ERPs to probes were analyzed by comparison with 4-target and 0-target neutral conditions, after subtraction of target-only ERPs. EEG was recorded from 30 leads. At 80 ms post-stimulus an NP80 was observed, with a relatively striate generator; it was not affected by attention. The earliest attention effect was found at 140 ms, with probes at the same location as the target eliciting larger, and those at a different location smaller positivity, compared to neutral. The estimated source of this effect was rather deep and medial, and slightly posterior. This result was consistently obtained across quadrants and attention conditions.

Psychophysiological evidence for a BIS defect in ADHD?

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In 1988 Quay proposed the application of the theoretical framework developed by Gray (1982) to childhood psychopathology. This framework concerns behavioral control under conditioned stimuli and its neuropsychological background. Although his proposal also deals with Anxious Withdrawn and Conduct Disordered children, this experiment focuses on children with Attention Deficit Hyperactivity Disorder (DSM-III-R, APA 1987). Following Fowles (1987) a serial reaction time task is used. Normal and ADHD children press buttons under reward, punishment, extinction and neutral conditions. Background EEG, heart rate, and skin conductance data were recorded, in order to test Quay's hypothesis that children with ADHD suffer from a dysfunctioning Behavioral Inhibition System (BIS).

Preliminary data analysis shows that normals and ADHD children do not differ in heart rate variation during the manipulation, indicating that there are no differences between the groups

in reward sensitivity, as predicted. Until now skin conductance data have not shown conclusive evidence for a dysfunction in BIS activity in ADHD children. EEG data show that there are differences between the groups in frontal activity during the task. Whether this might lead to a corroboration of Quay's hypothesis or not will be discussed during this presentation.

Stimulus preceding negativity

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Over the last few years we have performed a series of experiments in which we have tried to separate Movement Preceding Negativity from Stimulus Preceding Negativity. In essence this is possible by having subjects involved in a time estimation task. Subjects had to press a button after an estimated interval of 3 s following a warning stimulus. Two seconds later they were informed about the correctness of their performance by a Knowledge of Results (KR) stimulus, indicating whether the response was in time, too late or too early. Prior to the movement a readiness potential was recorded and prior to the KR stimulus an SPN. The former is larger over the hemisphere contralateral to the finger movement, the latter is larger over the right hemisphere. In order to challenge the right hemisphere preponderance we have recently studied the potential distribution prior to verbal KR, both in the auditory and the visual modality. The right hemisphere preponderance remained intact. In a PET study with de Jong the right hemisphere preponderance was again found. Predictions about areas of interest, based upon earlier work from our laboratory were confirmed.

The N400 priming effect: An index of lexical integration

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The N400 is especially sensitive to semantic processing. To assess the value of the N400 as a measure for psycholinguistic research it has to be clarified how it relates to the different lexical processes involved in language comprehension. In models of lexical processing a distinction is made between lexical access and lexical integration functions. Lexical access refers to the automatic process of accessing the mental lexicon and activating a subset of words and their semantic and syntactic attributes. Lexical integration refers to the more controlled process of integrating a lexical element into a higher-order meaning representation of the context.

The experiments investigated whether the N400 effect mainly reflects lexical access or lexical integration processes. The effects of lexical access and integration were distinguished by varying: (1) the levels of processing; (2) the proportion of related word pairs; (3) the temporal interval; and (4) by assessing whether the N400 effect reflects the early activation of multiple lexical candidates.

- Study 1. An N400 effect was found in a deep but not in a shallow processing task.
- Study 2. Increasing the proportion of related word pairs yielded an increase in the size of the N400 effect. This proportion effect is attributed to an expectancy mechanism.
- Study 3. N400 effects of equal size were obtained at short and long intervals. No interaction with interval was observed.
- Study 4. The results indicated that lexical selection must be completed before a spoken word provides the contextual information that yields N400 effects.

Taken together, the results yield a quite consistent picture: None of the studies provided evidence that links the N400 effect to the process of lexical access. In contrast, all N400 results support the notion that the N400 effect mainly reflects lexical integration processes.

ERPs to tones in the absence and presence of sleep spindles

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Data are reported from a study into the event-related potential (ERP) to auditory stimuli presented continuously during stage two sleep. Stage was determined using established criteria. EEG activity was recorded using a 10–20 system at 128 Hz. Spindle activity was detected online using a sleep analyzer on Cz data, and visually scored offline by three independent judges, to identify trials with spindle activity. Trials containing high amplitude, slow waves were excluded. Separate ERPs were obtained over trials in which spindle activity was present or absent for six university undergraduates in a three-tone oddball paradigm (ISI: 1 s). Only the ERP to standard stimuli (80%), presented at 65 dB(A), are reported here.

The unfiltered ERPs for the three midline leads (Fz, Cz, Pz) were entered into a MANOVA polynomial analysis. The number of data points was reduced to create 16 windows, each averaged over seven data points. Both condition (spindle present vs absent) and lead were entered in the analysis. The first 8 and last 8 windows were entered into separate analyses. Significant linear, quadratic and cubic effects were obtained for the early eight windows. Significant interactions were obtained between condition and the cubic polynomial for both sets of windows (early $F(5,1) = 17.86$, $P < 0.008$; late $F(5,1) = 6.55$, $P < 0.05$). The sustained positivity in the presence of spindle in the ERP was interpreted as evidence for inhibition of the further processing of external stimuli during spindle activity.

Central and autonomic indices of response inhibition

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In this study, central and autonomic indices of response inhibition were combined. Five subjects were engaged in a visual choice RT task. The response stimulus was an arrow pointing left or right. On 70% of the trials, it was colored green and the subjects had to make a response with the left or the right hand (GO trials). On 10% of the trials, it was colored red, and no response was to follow (NOGO trials). On 20% of the trials, the arrow was green, but after a variable interval it briefly turned red, upon which the subjects had to inhibit their response (STOP trials). The latency of the STOP signal was chosen so that the subjects could inhibit their response on half of the trials. ERPs were recorded from 28 electrodes, placed at 10–20 system positions and additional frontocentral sites. Heart rate, respiration, agonist and antagonist EMG, and continuous force recordings were also made.

The behavioral results fitted into a horse race model, in which independent activation and inhibition processes race for completion. Response inhibition was accompanied by heart beat slowing, which was largest when the stimulus was presented late in the cardiac cycle. The ERPs were characterized by a small transient (pre)frontal negativity followed by a large broad central positivity. Both components were larger on inhibition trials than in response trials. The first negative component was much smaller or absent in STOP trials than in NOGO trials, indicating that the underlying neurophysiological mechanisms may be different for these types of trials.

Early response activation on the basis of irrelevant information: LRP and EMG evidence for a direct-priming mechanism

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Processing of relevant information appears to be disturbed by the presentation of conflicting irrelevant information: responses are delayed when irrelevant, flanking arrow stimuli point in an opposite direction as compared to the direction of a simultaneously presented relevant target arrow. On the basis of recent behavioral research it was suggested that only target information undergoes a central S-R translation process. Irrelevant arrow stimuli seem to prime the response in the direction of that arrow, even when an incompatible response (i.e., left-hand response to a right-pointing arrow and vice versa) is required. In the present study, analyses were performed on the Lateralized Readiness Potential (LRP) and EMG to examine the direct-priming effects of irrelevant information on response activation.

In the first experiment, an arrow version of the Eriksen flanker task was used. Especially in the case of flanking arrows pointing in the opposite direction relative to the target arrow, direct priming effects became manifest: with incompatible S-R mappings, the typical initial incorrect lateralization (known as the Gratton-dip) was strongly attenuated. Furthermore, the percentages incorrect of early EMG responses were relatively low in the case of conflicting flanker arrows. In the second experiment, on some trials a response was to be withheld on the basis of a neutral target stimulus. It was found that on these NoGo trials, both in the compatible and incompatible situation, responses were activated initially in the direction of the flanking arrows. Together, these findings indicate that at least flanking arrows directly prime the naturally associated response, without undergoing a central S-R translation process.

Startle reflex modulation in spider phobics: Effects of monaural left and right ear stimulation

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There is evidence that the startle reflex is sensitive to emotional valence. For example, the startle reflex is reliably potentiated during the perception of frightening pictures and diminished during perception of pleasant pictures. In line with this, de Jong et al. (1993) showed that the startle magnitude of spider phobics was larger in the presence of a live spider than in the presence of tasty food items.

In addition, several lines of research suggest that the right cerebral hemisphere is more involved in the processing of phobic material than the left hemisphere. Given the evidence that anxiety is lateralized in the central nervous system, it might well be that affect-induced startle modulation is also lateralized. If startle modulation is, indeed, a lateralized phenomenon, this would imply that startle reflexes elicited by left ear stimulation might index affective valence more sensitively than those elicited by right ear probes or binaurally. Apart from this practical implication, a startle pattern indicating fear potentiation only for left ear probes would add to the evidence that the right hemisphere in particular is involved in the development and maintenance of anxiety.

To explore this issue, we presented monaural probes to 20 women who were spider phobic and who had applied for therapy. This was done in the presence of a live spider, a book, and tasty food items. Both left and right ear probes elicited blink magnitudes which increased linearly from pleasant to unpleasant foreground stimuli. Moreover, the affect-startle relationship was equal for right and left ear probes. Thus, no evidence emerged to support the idea that the affect-startle relationship is predominantly a function of the left ear.

Response-processes in ADHD and normal control children, a psychophysiological study

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In this study a variant of the Eriksen flanker task was used to investigate whether deficits in response-related processes could be found in children with Attention-Deficit-Hyperactivity-Disorder (ADHD). Besides performance, the following physiological measures were recorded to study stimulus evaluation, response preparation (at the central level) and response activation (peripheral) processes: Event-related brain potential (ERP); lateralized readiness potential (LRP); electromyographic activity (EMG).

Stimuli consisted of a single target arrow (to which a left or right hand button press was required), or the target flanked by arrows that were incongruent, congruent or neutral with the target. The task was performed by 14 ADHD and 14 control children and P3, LRP and EMG measures were recorded. ADHD subjects experienced a significantly larger interference effect from incongruent stimuli in the sense that they made more errors than normal controls. Significant interference effects from incongruent stimuli were present for all dependent variables, but in both groups. No group differences in reaction time, stimulus evaluation (P3 latency), response preparation (LRP onset latency) or response activation (EMG onset latency) were found.

It was concluded that, compared to control children, the presence of incongruent flankers caused a larger reduction of accuracy in ADHD children. However, when a correct response is given, ADHD subjects do not appear to be slower in stimulus evaluation, response preparation or activation processes. In contrast to what has been found in normal adults, patterns of incorrect response activation as induced by incongruent flankers could not be detected in the LRPs of ADHD and normal control children.

The modulation of color-cued selective attention event-related potentials (ERPs) by test connectivity

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Recent evidence has suggested that ERPs associated with color-cued selective attention may be modulated by language variables. In contrast to the selection negativity previously reported in color-cued selection studies, a long duration mid-latency positivity associated with attention (selection positivity) was recently reported in a color-cued selective attention paradigm utilizing connected text stimuli (Nobre & McCarthy, 1987). These experiments investigated this polarity reversal of color selective attention effects on ERPs

by systematically varying features of the Nobre paradigm, including the connectivity of the text, type of target stimuli, type of response, inclusion of function words and word repetitions, and stimulus onset asynchrony (SOA). The selection positivity was reliably elicited, and shown to be comprised of several overlapping subcomponents distinguishable on the basis of latency, scalp distribution, and the dependent influences of text connectivity and SOA variables. In addition, an unprecedented color-selection enhancement of the exogenous PI component, previously thought to form part of the ERP signature unique to spatial selection, was also observed. Elicitation of this early effect was shown to be sensitive to task demands as defined by response types. The implications of these findings for the temporal and neuroanatomical organization of cognitive processes are considered, and the data are interpreted within a context of a parallel, interactive attentional network under the control of an executive attentional system.

Event related potentials to deviant tones in light sleep in elderly males

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This study was designed to investigate the processing of deviant auditory stimuli in conditions of diminished alertness (reading, sleeping) in the elderly. A standard tone and two deviant tones (at approximately 65 dB(A)) were presented binaurally in an oddball paradigm to 14 healthy elderly males. Standards were presented in 80% of the trials and each deviant in 10% of the trials. These stimuli were quasi-randomly presented in stimulus blocks of 900 trials. Subjects were free of auditory defects. The stimuli (duration 50 ms, interstimulus interval approximately 1.2 s) were presented in several blocks until the subject awoke. EEG (Fz, Cz, Pz, T3, T4, A1 and A2, all referred to the inion), bipolar EOG and chin EMG were recorded. Electrode impedance was kept below 5 kOhm. The EEG was digitally sampled with a frequency of 128 Hz. Event-related potentials were computed for the ignore condition and stage two sleep. Sleep was scored according to accepted criteria. Trials containing artifacts were rejected offline and excluded from analysis. Visual analyses revealed a clear N1-P1 complex but no mismatch negativity to the deviant tones in either condition, suggesting that there is no difference in processing between the different tones. Our results do not accord with those of Pekkonen et al. (1993, *Electroencephalography & Clinical Neurophysiology, 87,* 321–325).

Linear estimation discriminates midline sources and a motor cortex contribution to the readiness potential

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Spatiotemporal dipole modelling of the generators of the readiness potential prior to voluntary movements have yielded diverging results concerning the contributions of SMA and primary motor cortex. One of the reasons may be the large amount of prior knowledge that is necessary for this approach. We applied an alternative approach (i.e., linear estimation theory) to measurements of the readiness potential preceding fixed and freely selected finger movements, measured at 28 electrodes of the extended 10–20 system. Linear estimation is a method for reconstructing brain activity from EEG and/or MEG measurements. It produces tomography-like pictures of the current density distribution within the brain and is capable of reconstructing distributed sources. One important advantage is that the solution does not require a non-linear optimization process and therefore cannot be trapped in local minima of the goal function. In the present paper linear estimation was used to reconstruct the sources of the readiness potential on a spherical surface underneath the skull. The volume conductor properties of the head were modeled by three concentric spheres. Current densities were reconstructed on a spherical surface, placed at a depth of 5 mm from the inside of the skull. Lead field normalization was applied. The analysis shows activity on the midline as well as near the primary motor area. Although some features of the reconstructions are not readily interpretable, the contribution of midline sources (including presumably SMA) and motor cortex to the readiness potential are clearly distinguished.

Functional brain mapping of preparatory processing in ADD children

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Children with attention deficit disorder (ADD) are characterized by impaired inhibitory control and inattention, which have both been linked to impaired (pre) frontal lobe functioning. It is not known to what extent impaired preparatory processes contribute to these deficits. CNV data from a continuous performance test (AX version) were recorded and analyzed with a variety of different procedures. High resolution (32-channel) functional ERP brain mapping, adaptive segmentation, and 3-dimensional centroid computation distinguished differences in strength, timing, and distribution of preparatory processing. Low resolution electromagnetic tomography localized the physiologically meaningful, 3-dimensional distribution of electric brain activity underlying these CNVs.

Performance on the CPT-AX clearly differentiated the ADD children from normal controls in terms of hits and false alarms. Electrophysiologically, ADD children generally displayed impaired early preparation and orienting to targets (i.e., to the warning letter A), rather than impaired response related target processing (i.e., to the letter X). The tomographic source solutions underlying this preparatory processing are posterior for both groups, so the preparatory deficit in ADD does not reflect a deficit in frontal lobe activation.

The effects of methylphenidate and diazepam on the acoustic startle reflex and prepulse inhibition in healthy volunteers

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The effects of the catecholamine reuptake blocker methylphenidate (Ritalin, 20 mg) and the benzodiazepine diazepam (Valium, 10 mg) on sensorimotor reactivity and prepulse inhibition (PPI) were assessed by examining the acoustic startle reflex. Twelve healthy young adults participated in an experiment in which the two drugs and placebo were given on separate days. Two types of startle stimuli were given: stand-alone and prepulse trials. Stand-alone trials were 85, 95 and 106 dB(A) 40 ms white noise stimuli, prepulse trials consisted of pulses of 106 dB(A) trials, 100 ms preceded by 20 ms lasting prepulses of 75, 80 or 85 dB(A).

The reactivity, as measured by eyeblink reflex amplitude, the area under the curve and reflex latency was found to be dependent on the intensity of the stand-alone trials. The prepulse reduced the amplitude of the startle reflex and the intensity of the prepulse determined the extent of PPI. The louder the intensity of the prepulse, the more PPI. The amplitude of the startle reflex on the stand-alone trials was slightly reduced by methylphenidate, the area under the curve was strongly reduced. Diazepam showed a large reduction in the amplitude and in the area under the curve of these reflexes. Prepulse inhibition was marginally reduced by methylphenidate, but strongly by diazepam. The effects of both drugs only partly agree with predictions based on animal literature. The diazepam data cast doubt on the specificity for DA-ergic agents to reduce PPI, they suggest that firm reductions in stand-alone trials might have major consequences for PPI. This challenges the validity of the theoretical construct of PPI.

Startle responses to subliminal phobic cues

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According to Öhman and co-workers (1993), phobias are experienced as involuntary because the fear response is initiated before the phobic stimulus reaches controlled conscious information processing levels. Evidence for this view comes from studies in which fearful subjects were confronted with subliminally presented pictures of phobic and neutral stimuli (e.g., Öhman & Soares, 1994). A mask prevented the subjects from perceiving these stimuli consciously. It was found that fearful subjects reacted with larger skin conductance responses (SCRs) specifically to their phobic stimuli. Because masking can be interpreted as blocking full conscious analysis of the stimuli, these results suggest that the auto-

nomic responses to the phobic stimuli were initiated by nonconscious automatic processes.

The present study differed in one important way from the experiment of Öhman and Soares: the dependent measure was the eyeblink startle response rather than the SCR. The eyeblink startle response was measured because this response is sensitive to emotional processes, whereas the SCR is more related to attentional processes such as orienting. Results of an earlier experiment (Merckelbach, de Jong, Leeuw & van den Hout, 1995) with the eyeblink startle response in spider phobic subjects yielded only suggestive evidence for an automatic analysis mechanism for fearful stimuli. The current experiment was an attempt to extend the previous findings. The results of this experiment will be detailed and discussed.

Effects of inter- and intramodal selective attention to nonspatial visual stimuli

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Although previous studies have suggested that intermodal visual attention effects on event-related potentials (ERPs) resemble the effects associated with intramodal visual attention, no conclusive evidence has yet been obtained that these two forms of visual selective attention involve the same mechanisms. In the present study ERPs to visual stimuli in conditions in which subjects attended to visual stimuli among other visual stimuli (line gratings), were compared with the ERPs to the same visual stimuli when subjects attended to auditory stimuli among other auditory stimuli (tone pips).

There were no indications that intermodal attention modulated exogenous N110/P140 and N180 to line gratings of low and high spatial frequencies, respectively. These results were confirmed both by topographic (CSD) and source analysis (BESA). Furthermore, intermodal visual attention effects on ERPs resembled the effects associated with intramodal visual attention. Like intramodal selective attention, effects of intermodal attention involved the occipital selection negativity and frontal selection positivity around 200–300 ms. However, intramodal visual attention produced a later onset of these selection potentials than intermodal attention. This probably indicates that a more precise stimulus selection is needed when visual stimuli are selected among other visual stimuli, than when the same stimuli are selected among stimuli of another modality.

Visual ERPs elicited in the auditory attention condition showed a large positive displacement at Oz in comparison with ERPs to attended and unattended visual stimuli in the visual attention condition. The relative early onset of this positivity might be associated with a highly confident and abrupt rejection of the irrelevant visual stimuli, when these stimuli are presented among auditory stimuli.

Motor inhibition and visual stop signals: The stop signal paradigm extended

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Most research on motor inhibition has been done within the framework of the Stop Signal Paradigm. In a stop task, subjects are engaged in a primary task, and occasionally, they are presented with a signal that tells them to stop their response to the primary task. The stop signal has typically been a tone. In the present study, the estimated stop signal reaction time (SSRT) in an auditory stop signal condition was compared to the SSRT in a visual stop signal condition and it was found that the former was significantly shorter than the latter. This might have been caused by the auditory stop-stimulus being more arousing. Furthermore, an experiment in which visual stop signals were presented in the right and left visual field has been conducted to test the hypothesis that there is a left-hemispheric superiority for motor-stopping. This hypothesis originates from the classical distinction between two neural systems controlling arousal and activation: the arousal system, preferentially mediated by the right hemisphere, produces a phasic response to perceptual input and the activation system, preferentially mediated by the left hemisphere, is integral to motor operations and tonic readiness to respond. The observed interaction between visual half field and response hand confirmed the predicted right visual field-advantage. Apparently, the present stop task might be considered a typical activation-task. Finally, some relevant remarks are made with respect to the issue of setting stop signal delay and, thereby, compensating for differences between subjects or conditions in primary-task reaction time.

The development of selective attention as indexed by heart rate

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Between- and within-channel auditory selective attention was examined in two groups of children aged 7 and 11 years by presenting tone pips of different pitch randomly to opposite ears. Some of the pips had a slightly higher pitch. The children were instructed to count the deviant pips in one ear and to ignore all pips in the other ear. The number of frequent pips which preceded a rare pip was varied. Series of frequent pips which ended with a rare pip varied between 4, 8, and 12. Cardiac interbeat intervals were sampled during presentation of the attended tone pips and during the non-attended tone pips. The cardiac interbeat intervals responded differently to the attended tone pips. Initially the heart was slowed when the rare pip was presented, followed by increased heart rate when the subject was counting. When adult subjects waited for the rare tone to occur, their heart rate slowed until the deviant stimulus was detected after which the heart rate accelerated. This expectancy response was absent in the youngest children and present in the older children only for the series of 4 and 8 pips. In the non-attended series no anticipatory deceleration occurred. A small, but significant deceleration to the rare tones indicated that rare tones in the irrelevant channel were also detected. This response was stronger in the youngest children. The youngest children made relatively more counting errors. These results indicate that the developmental rates of the different selective attention functions are not the same; tone discrimination and channel separation were present, but not fully in the youngest group, whereas expectancy was not yet completely present at 12 years.

Brain activity and visual working memory

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Baddeley's working memory model assumes that information can be retained for a short time as a modality specific representation. The model contains two subsystems: the articulatory loop and the visuo-spatial scratch pad. Our goal is to answer the question of whether visual working memory is correlated with activity in occipital areas of the brain. The influence of mental translations on the contents of the visual buffer was also investigated. A visual memory task was developed during which ERPs as well as reaction times were recorded. Two polygon-like stimuli were presented, one in each visual half field. Either one or both stimuli had to be retained in memory for 1.5 seconds, after which a test stimulus was presented. This test stimulus could be equal to or differ from the stimulus material held in memory. Also, the test stimulus could be presented ipsi- or contralateral, compared to the material held in memory.

Evidence is found from the ERP results, that visual working memory processes are located in the occipital brain areas of the hemisphere contralateral to the visual half field containing a stimulus to be retained. A prolonged negative shift was found, that is associated with the activation of these areas. A positive shift during high memory load conditions however, suggests that visual memory is controlled by a central attentional system. During the presentation of the test stimulus, ERP and reaction time measurements show that targets and non-targets are processed differently. The absence of activation in visual areas during this interval suggests that when material in visual working memory is needed for further processing, it is recorded to a non-modality specific code.

Measurement of mental workload in a flight simulator

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Mental workload was measured in a series of experiments in a flight simulator. Pilots had to follow a target plane at fixed distances and in some conditions, they had to perform an auditory counting task. The workload was measured with a rating scale, heart rate (HR), continuous blood pressure (BP), respiration, and eye blinks. Spectral analysis was obtained for HR and BP to determine the variability in the mid-band (0.07–0.14 Hz) and high-band (0.15–0.50 Hz) as well as to calculate the gain between changes in BP and HR. This gain is believed to index the sensitivity of the baroreceptors. Workload was varied by manipulating the difficulty of the flight task and the secondary task. In general, HR and BP were affected by changes in workload, but this was not always the case for heart rate variability (HRV). This was caused by intrusion of respiration; especially after a period of high

workload, subjects tended to breath deeply which increased the HRV, in particular in the mid-band. The gain between BP and HR reduced as a function of workload and was hardly affected by respiration. In complex tasks in which changes in respiratory activity occur frequently, the gain between BP and HR is a more reliable index of mental workload than HRV. Eye blinks proved to be a measure of the visual demands in the task. The number and duration of eye blinks decreased if more visual information had to be processed. Blink rate increased as the set size of the secondary task increased. It is assumed that this is caused by the rehearsal of the target letters to keep the separate tallies in working memory.

Ignored listening: The relation between ERPs and remembering

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Data are reported from an event-related potential (ERP) study of differential processing of words that were later recognized and not recognized. Electroencephalographic activity was recorded using the 10–20 system at 200 Hz. Sixteen subjects performed three successive tasks. (1) The familiarization task: subjects counted non-words intermixed with normal words spoken in a male voice. Word length varied between 350 and 500 ms. (2) The ignore task: subjects viewed a silent video, over which they subsequently answered questions, during an oddball presentation (20 percent of the words were in a woman's voice and 80% in a male voice). (3) The recognition task: subjects listened to a long list of words and had to indicate whether they recognized a word as having been presented to them previously or not. Subjects were divided into "good performance" and "bad performance" groups.

Visual inspection of grand average ERP plots produced the following observations: Stimulus onset and offset ERPs in the familiarization task showed differential processing between words and non-words after 600 ms and around 250 ms, respectively. Stimulus onset ERPs in the ignore condition showed differential processing of deviant and standard words around 300 ms. This was more pronounced in the "good performance" group. Stimulus offset ERPs of the ignore task showed no differential processing between recognized and non-recognized words. Stimulus offset ERPs to deviants in the ignore task showed possible differential processing between recognized and not-recognized words within 100 ms.